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(54) Ink compositions.

(57) Disclosed is an ink composition which comprises an aqueous liquid vehicle and particles of an average diameter of 100 nanometers or less which comprise micelles of block copolymers of the formula ABA, wherein A represents a hydrophilic segment and B represents a hydrophobic segment, and wherein dye molecules are covalently attached to the micelles, the dye molecules being detectable when exposed to radiation outside the visible wavelength range. Optionally, silica is precipitated within the micelles. In a specific embodiment, the dye molecules are substantially colorless. In another specific embodiment, the ink also contains a visible colorant.

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The present invention is directed to ink compositions and printing processes. More specifically, the present invention is directed to ink compositions containing polymolecular micelles of a block copolymer having dye molecules attached to the micelle surfaces, and to printing processes employing such inks. One embodiment of the present invention is directed to an ink composition which comprises an aqueous liquid vehicle and particles of an average diameter of 100 nanometers or less which comprise micelles of block copolymers of the formula ABA, wherein A represents a hydrophilic segment, B represents a hydrophobic segment, and wherein dye molecules are covalently attached to the micelles. Optionally, silica is precipitated within the micelles. In another specific embodiment, the dye is selected so that the particles are detectable when exposed to radiation outside the visible wavelength range. In yet another specific embodiment, the dye is selected so that the particles are substantially colorless and detectable when exposed to radiation outside the visible wavelength range. The inks of the present invention are particularly suitable for ink jet printing processes.

Ink jet printing systems generally are of two types: continuous stream and drop-on-demand. In continuous stream ink jet systems, ink is emitted in a continuous stream under pressure through at least one orifice or nozzle. The stream is perturbed, causing it to break up into droplets at a fixed distance from the orifice. At the break-up point, the droplets are charged in accordance with digital data signals and passed through an electrostatic field which adjusts the trajectory of each droplet in order to direct it to a gutter for recirculation or a specific location on a record medium. In drop-on-demand systems, a droplet is expelled from an orifice directly to a position on a record medium in accordance with digital data signals. A droplet is not formed or expelled unless it is to be placed on the record medium.

Since drop-on-demand systems require no ink recovery, charging, or deflection, they are much simpler than the continuous stream type. There are two types of drop-on-demand ink jet systems. One type of drop-on-demand system has as its major components an ink-filled channel or passageway having a nozzle at one end and a piezoelectric transducer near the other end to produce pressure pulses. The relatively large size of the transducer prevents close spacing of the nozzles, and physical limitations of the transducer result in low ink drop speed. Low drop speed seriously diminishes tolerances for drop speed variation and directionality, thus impacting the system's ability to produce high-quality copies. Drop-on-demand systems which use piezoelectric devices to expel the droplets also suffer the disadvantage of a slow printing speed.

The second type of drop-on-demand system is known as thermal ink jet, or bubble jet, and produces high speed droplets and allows very close spacing of nozzles. The major components of this type of drop-on-demand system are an ink-filled channel having a nozzle at one end and a heat-generating resistor near the nozzle. Printing signals representing digital information originate an electric current pulse in a resistive layer within each ink passageway near the orifice or nozzle, causing the ink in the immediate vicinity to evaporate almost instantaneously and create a bubble. The ink at the orifice is forced out as a propelled droplet as the bubble expands. When the hydrodynamic motion of the ink stops, the process is ready to start all over again. With the introduction of a droplet-ejection system based up on thermally-generated bubbles, commonly referred to as the "bubble jet" system, the drop-on-demand ink jet printers provide simpler, lower-cost, devices than their continuous stream counterparts, and yet have substantially the same high speed printing capability.

The operating sequence of the bubble jet system begins with a current pulse through the resistive layer bounding the ink-filled channel, the resistive layer being in close proximity to the orifice or nozzle for that channel. Heat is transferred from the resistor to the ink. The ink becomes superheated far above its normal boiling point and, for water-based ink, finally reaches the critical temperature for bubble formation or nucleation of around 280°C. Once nucleated, the bubble of water vapor thermally isolates the ink from the heater and no further heat can be applied to the ink. This bubble expands until all the heat stored in the ink in excess of the normal boiling point diffuses away or is used to convert liquid to vapor, which removes heat because of heat of vaporization. The expansion of the bubble forces a droplet of ink out of the nozzle, and once the excess heat is removed, the bubble collapses on the resistor. At this point, the resistor is no longer being heated because the current pulse has ceased and, concurrently with the bubble collapse, the droplet is propelled at high speed in a direction towards a record medium. The resistive layer encounters a severe cavitation force by the collapse of the bubble, which tends to erode it. Subsequently, the ink channel refills by capillary action. This entire bubble formation and collapse sequence occurs in about 10 microseconds. The channel can be refired after 100 to 500 microseconds minimum dwell time to enable the channel to be refilled and to enable the dynamic refilling factors to become somewhat dampened. Thermal ink jet processes are well known and are described, for example, in US-A-4,601,777, 4,251,824, 4,410,899, 4,412,224 and 4,532,530.

Known ink jet inks generally comprise a water-soluble dye which is soluble in water or a mixture comprising water and a water-soluble or water-miscible organic solvent. Inks comprising soluble dyes may exhibit many problems, such as poor waterfastness, poor lightfastness, clogging of the jetting channels as a result of solvent evaporation and changes in the solubility of the dye, dye crystallization, ink bleeding when prints are formed on plain papers, poor thermal stability, chemical instability, ease of oxidation, and low drop speed. In addition,

many of the dyes contained in inks may be potentially toxic or mutagenic. These problems can be minimized by replacing the dyes used in ink formulations with insoluble pigments. In general, pigments are superior to dyes with respect to waterfastness, lightfastness, image density, thermal stability, oxidative stability, compatibility with both coated/treated and plain papers, image edge acuity, reduced image feathering, and non-toxic and non-mutagenic properties.

Heterophase ink jet inks are known. For example, US-A-4,705,567 discloses a heterophase ink jet ink composition which comprises water and a dye covalently attached to a component selected from the group consisting of poly(ethylene glycols) and poly(ethylene imines), which component is complexed with a heteropolyanion. In addition, US-A-4,597,794 discloses an ink jet recording process which comprises forming droplets of an ink and recording on an image-receiving material by using the droplets, wherein the ink is prepared by dispersing fine particles of a pigment into an aqueous dispersion medium containing a polymer having both a hydrophilic and a hydrophobic construction portion. The hydrophilic portion constitutes a polymer of monomers having mainly polymerizable vinyl groups into which hydrophilic portions such as carboxylic acid groups, sulfonic acid groups, sulfate groups, and the like are introduced. Pigment particle size may be from several to several hundred micrometres. The ink compositions disclosed may also include additives such as surfactants, salts, resins, and dyes.

US-A-4,877,451 discloses ink jet ink compositions comprising water, a solvent, and a plurality of colored particles comprising hydrophilic porous silica particles to the surfaces of which dyes are covalently bonded through silane coupling agents.

Heterophase inks containing pigment particles as colorants, however, also exhibit difficulties. For example, the particulate colorant may exhibit a tendency to settle out or separate from the liquid vehicle, particularly when the ink is stored for long periods. In addition, inks containing pigment particles as colorants tend to be opaque instead of transparent, which reduces their usefulness for printing images on transparencies for the purpose of overhead projection. Further, inks containing pigment particles as colorants tend to clog the narrow orifices of the printhead, resulting in deterioration of the print quality.

Accordingly, there is a need for inks having the advantages of both dye-based inks and pigment-based inks. The present invention is directed to an ink composition which comprises a liquid vehicle and colored particles of an average diameter of 100 nanometers or less which comprise micelles of block copolymers of the formula ABA, wherein A represents a hydrophilic segment and B represents a hydrophobic segment, and wherein dye molecules are covalently attached to the micelles. Optionally, silica is precipitated within the micelles.

US-A-4,552,914 discloses a thermoplastic elastomeric hydrocarbon block copolymer having 0.1 to 8 percent polysiloxane or silicone oil uniformly distributed throughout. The block copolymer may be styrene-ethylene-butylene-styrene, in which the styrene blocks have a molecular weight of 5,000 to 40,000, and the ethylene-butylene block has a molecular weight of 20,000 to 500,000. The copolymer is combined with the silicone oil under the influence of a pressure of 10.3 to 17.2 MN<sub>m-2</sub>, such as provided by extrusion blending. The composition exhibits improved surface, elasticity, and tensile strength characteristics as well as superior processability.

US-A-4,267,310 discloses a process for producing uniformly spherical particles of crystalline, normally-solid, condensation polymers by forming a dispersion of small liquid particles of the crystalline polymer in aprotic liquids containing 0.1 to 20 percent by weight of the polymer of a water-insoluble block or graft copolymer having at least one polymeric component which is soluble in the aprotic liquid and at least one other polymeric component which is insoluble in the aprotic liquid and associates with the crystalline polymer. The dispersion is cooled with agitation until the liquid particles solidify, and the particles are then recovered.

US-A-4,153,587 discloses a modified propylene polymer containing mixed polymer composition characterized by high tensile strength, high elongation, and good bending stiffness. The material consists essentially of a crystalline polypropylene, a block copolymer wherein a propylene-ethylene random copolymer is chain-terminated onto the crystalline polypropylene, and a crystalline ethylene-propylene random copolymer having an ethylene content of more than about 90 percent by weight, wherein the modified polypropylene polymer is admixed with at least 30 percent by weight of an inorganic filler having an average particle size of less than 20 μm in diameter.

Although known compositions are suitable for their intended purposes, a need remains for ink compositions exhibiting advantages of both dye-based inks and pigment-based inks. There is also a need for ink compositions with good waterfastness characteristics. A need also remains for ink compositions exhibiting good lightfastness characteristics. Further, there is a need for ink compositions that are non-toxic and non-mutagenic. In addition, a need exists for ink compositions for which a wide variety of color choices exists. There is also a need for ink compositions that can be prepared by simple and inexpensive processes. A need also exists for ink compositions which comprise stable particulate suspensions with long shelf life. Further, there is a need for ink compositions suitable for printing on plain papers, coated or treated papers, and transparency materials. In

addition, there is a need for ink compositions that when printed on substrates exhibit good optical density, low feathering, and excellent rub-resistance. There is also a need for ink compositions that when used to print on transparency materials generate images that project their original colors well when light is passed through the image. A need also remains for ink compositions with good thermal and oxidative stability. Further, there is a need for ink compositions suitable for ink jet printing that do not induce clogging of the printhead. A need also remains for ink compositions that when printed on substrates exhibit no undesirable intercolor bleeding between areas of different color. In addition, there is a need for ink compositions that are invisible to the human eye under normal viewing conditions but readable by a sensor, such as an infrared detector or a fluorescence detector, or by the human eye under special viewing conditions such as illumination of the image with ultraviolet light. There is also a need for ink compositions that are visible to the human eye under normal viewing conditions and are also readable by a sensor that detects wavelengths invisible to the human eye, such as an infrared detector or a fluorescence detector, or by the human eye under special viewing conditions such as illumination of the image with ultraviolet light. Further, there is a need for ink compositions that can provide a means for placing coded information on a document.

It is an object of the present invention to provide ink compositions exhibiting advantages of both dye-based inks and pigment-based inks.

Accordingly the present invention provides an ink composition which comprises an aqueous liquid vehicle and particles of an average diameter of 100 nanometers or less which comprise micelles of block copolymers of the formula ABA, wherein A represents a hydrophilic segment and B represents a hydrophobic segment, and wherein dye molecules are covalently attached to the micelles. In a specific embodiment of the present invention, the particles comprise micelles of block copolymers of the formula ABA having silica precipitated therein and dye molecules covalently attached to the micelles. In another specific embodiment of the present invention, the dye is selected so that the particles are detectable when exposed to radiation outside the visible wavelength range. In yet another specific embodiment of the present invention, the dye is selected so that the particles are substantially colorless and detectable when exposed to radiation outside the visible wavelength range. Another embodiment of the present invention is directed to a printing process which comprises incorporating an ink of the present invention into an ink jet printing apparatus and causing droplets of the ink to be ejected in an imagewise pattern onto a substrate, thereby generating images on the substrate. Yet another embodiment of the present invention is directed to an ink preparation process which comprises, in the order stated (1) adding to water a block copolymer of the formula ABA, wherein A represents a hydrophilic segment and B represents a hydrophobic segment, thereby forming a dispersion of micelles of the block copolymer; (2) adding a water-soluble base to the dispersion, thereby bringing the pH of the dispersion to at least 8; (3) adding to the dispersion a solution comprising water and a reactive dye capable of reacting with the block copolymer, thereby forming dyed polymeric micelles; and (4) admixing the dyed micelles with an aqueous liquid vehicle to form an ink composition. Still another embodiment of the present invention is directed to an ink preparation process which comprises, in the order stated (1) adding to water a block copolymer of the formula ABA, wherein A represents a hydrophilic segment and B represents a hydrophobic segment, thereby forming a dispersion of micelles of the block copolymer; (2) admixing a tetraalkoxysilane with the dispersion; (3) adding a water-soluble base to the dispersion, thereby bringing the pH of the dispersion to at least 8, thereby precipitating silica within the micelles; (4) adding to the dispersion a solution comprising water and a reactive dye capable of reacting with the block copolymer, thereby forming dyed polymeric micelles with silica precipitated therein; and (5) admixing the dyed micelles with an aqueous liquid vehicle to form an ink composition.

The liquid vehicle of the inks of the present invention may consist of water, or it may comprise a mixture of water and a miscible organic component, such as ethylene glycol, propylene glycol, diethylene glycols, glycerine, dipropylene glycols, polyethylene glycols, polypropylene glycols, amides, ethers, carboxylic acids, esters, alcohols, organosulfides, organosulfoxides, sulfones, dimethylsulfoxide, sulfolane, alcohol derivatives, carbitol, butyl carbitol, cellusolve, ether derivatives, amino alcohols, ketones, and other water-miscible materials, as well as mixtures thereof. When mixtures of water and water-miscible organic liquids are selected as the liquid vehicle, the water to organic ratio may be in any effective range, and typically is from about 100:0 to about 30:70, preferably from about 97:3 to about 50:50. The non-water component of the liquid vehicle generally serves as a humectant which has a boiling point higher than that of water (100°C). The liquid vehicle should permit an emulsion or a colloidal suspension of the colored particles in the ink, and should have evaporation characteristics allowing for the desired ink jet printing speed if the ink is to be used in an ink jet printing process. In the inks of the present invention, the liquid vehicle is generally present in an amount of from about 85 to about 99.5 percent by weight, and preferably from about 90 to about 99 percent by weight.

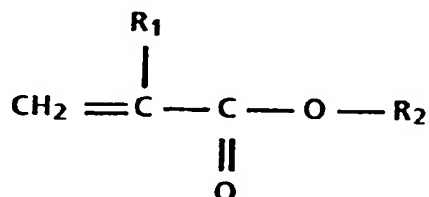
Optional additives to the inks prepared by the process of the present invention include biocides, such as Dowicil 150, 200, and 75, benzoate salts, sorbate salts, and the like, present in an amount of from about 0.0001 to about 4 percent by weight, and preferably from about 0.01 to about 2.0 percent by weight; humectants such

as ethylene glycol, diethyleneglycol, N-methylpyrrolidinone, propylene glycol, hydroxyethers, ethers, amides, sulfoxides, ketones, lactones, esters, alcohols, and the like, present in an amount up to 50 percent by weight, and preferably from 5 to 40 percent by weight, and pH-controlling agents such as acids or bases, phosphate salts, carboxylates salts, sulfite salts, amine salts, and the like present in an amount up to 1 percent by weight

The inks of the present invention contain polymeric micelles to which are attached dye molecules. The polymeric micelles comprise polymolecular aggregates, generally with an average diameter of about 100 nanometers or less, of a block copolymer the block copolymer is of the ABA type, wherein the outer A segments are hydrophilic and the inner B segment is hydrophobic. The terms hydrophobic and hydrophilic as used herein are relative, in that the polymer contains two A segments and a B segment, wherein the A segments are hydrophilic with respect to the B segment. The A segments also exhibit good water solubility, typically being soluble in water in a concentration of at least about 0.2 grams per milliliter, while the B segment exhibits poor water solubility, typically being soluble in water in a concentration of no more than about 0.01 grams per milliliter. When dispersed in water at concentration of, for example, from about 0.05 to about 10 grams per liter, the block copolymers form polymolecular micelles with a hydrophobic core and a hydrophilic shell, said micelles generally having an average diameter of 100 nanometers or less.

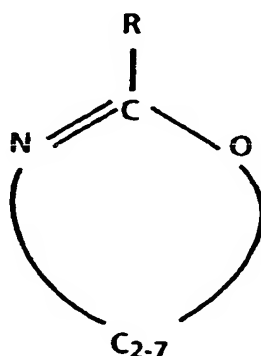
Examples of suitable monomers for the A block include oxyethylene monomers and aminoethylene monomers. The number of oxyethylene monomers per block typically is from 5 to 400 monomeric units, and preferably from 50 to 300 monomeric units.

Also suitable are vinyl carboxylic acids and their corresponding esters of the general formula:



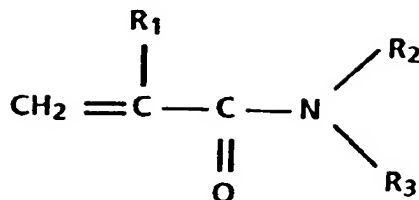
wherein  $\text{R}_1$  and  $\text{R}_2$  are independently selected from hydrogen and alkyl groups with from 1 to about 20 carbon atoms, including acrylic acid, methacrylic acid, paracarboxystyrene, and the like.

Also suitable are oxazolines of the general formula



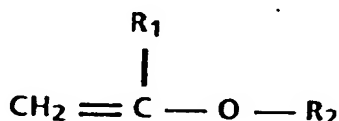
wherein  $\text{R}$  is hydrogen, an alkyl group with from 1 to about 6 carbon atoms, or benzyl and the ring has from 2 to 7 carbon atoms in addition to the carbon atom situated between the nitrogen and oxygen atoms, including ethyloxazoline, and the like.

Also suitable are acrylamides of the general formula



wherein R<sub>1</sub> is hydrogen, methyl, or ethyl, and R<sub>2</sub> and R<sub>3</sub> are independently selected from hydrogen, alkyl groups with from 1 to about 4 carbon atoms, hydroxyalkyl groups with from 1 to about 4 carbon atoms, such as 2-hydroxyethyl, 2-hydroxypropyl, 3-hydroxypropyl, 2-hydroxybutyl, 3-hydroxybutyl, 4-hydroxybutyl, and the like, and amino-substituted alkyl groups, such as 2-aminoethyl, 2-aminopropyl, 3-aminopropyl, 2-aminobutyl, 3-aminobutyl, 4-aminobutyl, and the like.

Also suitable are vinyl ethers of the general formula



wherein R<sub>1</sub> is selected from the group consisting of hydrogen, methyl, and ethyl, and R<sub>2</sub> is selected from hydroxy-substituted alkyl groups, such as 2-hydroxyethyl, 2-hydroxypropyl, 3-hydroxypropyl, 2-hydroxybutyl, 3-hydroxybutyl, 4-hydroxybutyl, and the like, and amino-substituted alkyl groups, such as 2-aminoethyl, 2-aminopropyl, 3-aminopropyl, 2-aminobutyl, 3-aminobutyl, 4-aminobutyl, and the like. Mixtures of two or more monomers can also be employed in the hydrophilic block. In addition, the two A segments in the ABA block copolymer employed for the present invention need not be of identical composition, but can each be of different monomers, structure, and/or composition.

The molecular weight of each A segment or block is such that the segment is soluble in water. Typically, the molecular weight of each A segment is from 500 to 20,000 (average molecular weight), although the molecular weight can be outside of this range.

Examples of suitable monomers for the B block include oxypropylene monomers; the number of oxypropylene groups typically is from 5 to 100 monomeric units, and preferably from 20 to 60 monomeric units. Other suitable monomers for the B block include vinyl monomers, such as styrene, styrene derivatives and congeners such as alkyl styrenes wherein the alkyl group has from 1 to about 20 carbon atoms, halogenated styrenes such as p-chlorostyrene, vinyl naphthalene, and the like, vinyl halides such as vinyl chloride, vinyl bromide, vinyl fluoride, and the like, vinyl ethers, such as methyl vinyl ether, vinyl ethyl ether, and the like, vinyl ketones, such as vinyl methyl ketone and the like, N-vinyl indole and N-vinyl pyrrolidone, vinyl esters, such as vinyl acetate, vinyl propionate, vinyl benzoate, and vinyl butyrate, and the like; acrylic monomers and esters of monocarboxylic acids, such as acrylates and alkylacrylates with the alkyl group having at least 1 carbon atom, and generally from 1 to 12 carbon atoms, such as methacrylates, methylacrylates, ethacrylates, ethylacrylates, and the like, including methyl acrylate, ethyl acrylate, n-butylacrylate, isobutyl acrylate, dodecyl acrylate, n-octyl acrylate, 2-chloroethyl acrylate, phenyl acrylate, methylalpha-chloroacrylate, methyl methacrylate, ethyl methacrylate, butyl methacrylate, and the like; acrylic monomers and esters of monocarboxylic acids, such as acrylates and alkylacrylates with the alkyl group having at least 1 carbon atom and 1 hydroxy group, and generally from 2 to 12 carbon atoms, such as 2-hydroxyethyl methacrylate, 2-hydroxyethyl acrylate, 3-hydroxypropyl methacrylate, 3-hydroxypropyl acrylate, 4-hydroxybutyl methacrylate, 4-hydroxybutyl acrylate, and the like; olefins, including monoolefins and polyolefins, such as ethylene, propylene, butylene, butadiene, isobutylene, cycloolefins, such as cyclopentene. The hydrophobic segment can also be derived by the condensation polymerization of difunctional monomers to yield polyesters, polyamides, polyurethanes, or the like, such as polyethyleneterephthalate, polyhexamethylene adipamide (nylon 6,6), or the like. Mixtures of two or more monomers can also be employed in the hydrophobic block.

The molecular weight of the B segment or block is such that the segment is insoluble in water. Typically, the molecular weight of the B segment is from 500 to 20,000 (average molecular weight), although the molecular weight can be outside this range.

Examples of suitable ABA block copolymers for the present invention include Pluronic F-68, an ethylene

oxide-propylene oxide-ethylene oxide block copolymer wherein the ethylene oxide blocks have an average molecular weight of 3340 and the propylene oxide block has an average molecular weight of 1750, available from BASF; Pluronic F-38, an ethylene oxide-propylene oxide-ethylene oxide block copolymer wherein the ethylene oxide blocks have an average molecular weight of 2000 and the propylene oxide block has an average molecular weight of 950; Pluronic F-88, an ethylene oxide-propylene oxide-ethylene oxide block copolymer wherein the ethylene oxide blocks have an average molecular weight of 4320 and the propylene oxide block has an average molecular weight of 3250; Pluronic F-98, an ethylene oxide-propylene oxide-ethylene oxide block copolymer wherein the ethylene oxide blocks have an average molecular weight of 5400 and the propylene oxide block has an average molecular weight of 2750; and Pluronic F-108, an ethylene oxide-propylene oxide-ethylene oxide block copolymer wherein the ethylene oxide blocks have an average molecular weight of 5600 and the propylene oxide block has an average molecular weight of 3250, available from BASF.

Other suitable ABA block copolymers for the present invention include amphiphilic block copolymers of vinyl ethers, prepared for example by living cationic polymerization, as described in M. Minoda, M. Sawamoto, and T. Higashimura, *Macromolecule*, 23, 1989, 1990, wherein the A blocks are 2-hydroxyethyl vinyl ether polymers of average molecular weight 2000, and the B block is a polymer of butyl vinyl ether of average molecular weight 1500. Other suitable ABA block copolymers for the present invention include block copolymers of ethylene oxide and 2-hydroxyethyl methacrylate, prepared for example as described in M. Ikemi, N. Odagiri, and I. Shinohara, *Polymer journal*, 12, 777, 1980, wherein the ethylene oxide blocks have an average molecular weight of 7200 and the 2-hydroxyethyl methacrylate block has an average molecular weight of 1900.

To prepare the dyed polymeric micelles, the selected block copolymer is first admixed with water, preferably water that has been distilled or deionized. The block copolymer is added to the water in an amount sufficient to ensure micelle formation, and generally is added in a concentration of from 0.05 to 5 percent by weight. The polymolecular micelles obtained are of an average diameter of about 100 nanometers or less. Subsequently, a water-soluble base, such as aqueous ammonium hydroxide, sodium hydroxide, organic amines such as methyl amine, ethyl amine, and propyl amine, or the like, is added to the dispersion of micelles in an amount sufficient to raise the pH of the dispersion to at least 8. Typically, the base is added to the dispersion in an amount of from 5 to 20 percent by weight of the total dispersion. A solution of a reactive dye dissolved in water, typically at a concentration of from 1 to 10 percent by weight, is then added to the dispersion, generally at room temperature, typically in an amount so that the dye molecules are present in an amount of from 5 to 30 percent by weight of the micelles. When the reaction between the dye and the polymeric micelles has completed (typically within about 24 hours), the mixture is purified by an ultrafiltration process using, for example, membranes with a molecular weight cut-off of 100,000 to remove excess reactive dye and other low molecular weight impurities. Subsequent to purification, the suspension of dyed micelles can be concentrated for use in an ink or isolated by freeze-drying.

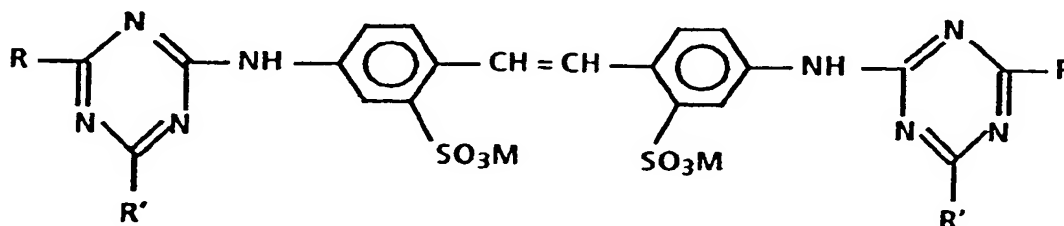
In one specific embodiment of the present invention, the dyed polymeric micelles comprise a hydrophobic core and a hydrophilic shell, the micelles having silica precipitated therein, wherein dye molecules are attached to the micelle surfaces. The dyed micelles are prepared by first admixing the selected block copolymer with water, preferably distilled or deionized water, generally in a concentration of from 0.05 to 5 percent by weight to obtain polymolecular micelles of an average diameter of about 100 nanometers or less. Subsequently, a tetraalkoxysilane wherein the alkyl group has from one to about 6 carbon atoms, such as tetraethoxysilane, is added to the dispersion of micelles, typically in a relative amount of from 1 to 30 percent by weight of micelles, and the dispersion is stirred until silica has precipitated into the micelles. Additional examples of suitable silane materials include tetramethoxysilane, tetra-n-propoxysilane, tetra-i-propoxysilane, tetra-n-butoxysilane, tetra-s-butoxysilane, tetra-i-butoxysilane, tetrapentoxysilane, tetrakis-(2-methoxyethoxysilane), and the like. Thereafter, a water-soluble base, such as aqueous ammonium hydroxide, sodium hydroxide, organic amines such as for example methyl amine, ethyl amine, and propyl amine, or the like, is added to the dispersion of micelles in an amount sufficient to raise the pH of the dispersion to at least 8, and a solution of a reactive dye dissolved in water typically at a concentration of from 1 to 10 percent by weight is added to the dispersion, generally at room temperature, typically in an amount so that the dye molecules are present in an amount of from 5 to 30 percent by weight of the micelles. When the reaction between the dye and the polymeric micelles has completed (typically within about 24 hours), the mixture is purified by an ultrafiltration process using, for example, membranes with a molecular weight cut-off of 100,000 to remove excess reactive dye and other low molecular weight impurities. Subsequent to purification, the suspension of dyed micelles can be concentrated for use in an ink or isolated by freeze-drying. It is believed that the network of silica precipitated within the polymeric micelles enhances the properties of an ink containing the particles, particularly with respect to thermal stability.

The dyes suitable for the present invention generally include any of the reactive dyes capable of reacting with the block copolymer micelles to become attached thereto. These dyes typically comprise a chromophore soluble in water, such as an anthraquinone, a monoazo dye, a disazo dye, a phthalocyanine, an aza[18]annu-



lene, a formazan copper complex, a triphenyldioxazine, and the like, to which is covalently attached a reactive group, such as a dichlorotriazine, a monochlorotriazine, a dichloroquinoxaline, an aminoepoxide, a mono-(m-carboxypyridinium)-triazine, a 2,4,5-trihalogenopyrimidine, a 2,4-dichloropyrimidine, a 2,3-dichloroquinoxaline, a monofluorotriazine, a 4,5-dichloro-6-methyl-2-methylsulfonylpyrimidine, a 1,4-dichlorophthalazine, a chloro-benzo-thiazole, a sulfatoethylsulfone, a  $\beta$ -chloroethylsulfone, a 4,5-dichloro-6-pyridazone, an  $\alpha$ -bromoac-  
 5 ryloylamido, an  $\alpha,\beta$ -dibromopropionylamido, and the like. Examples of suitable dyes include Levafix Brilliant Yellow E-GA, Levafix Yellow E2RA, Levafix Black EB, Levafix Black E-2G, Levafix Black P-36A, Levafix Black PN-L, Levafix Brilliant Red E6BA, and Levafix Brilliant Blue EFFA, available from Bayer, Procion Turquoise PA, Procion Turquoise HA, Procion Turquoise H-5G, Procion Turquoise H-7G, Procion Red MX-5B, Procion  
 10 Red MX 8B GNS, Procion Red G, Procion Yellow MX-8G, Procion Black H-EXL, Procion Black P-N, Procion Blue MX-R, Procion Blue MX-4GD, Procion Blue MX-G, and Procion Blue MX-2GN, available from ICI, Cibacron Red F-B, Cibacron Black BG, Lanazol Black B, Lanazol Red 5B, Lanazol Red B, and Lanazol Yellow 4G, avail-  
 15 able from Ciba-Geigy, Basilen Black P-BR, Basilen Yellow EG, Basilen Brilliant Yellow P-3GN, Basilen Yellow M-6GD, Basilen Brilliant Red P-3B, Basilen Scarlet E-2G, Basilen Red E-B, Basilen Red E-7B, Basilen Red M-5B, Basilen Blue E-R, Basilen Brilliant Blue P-3R, Basilen Black P-BR, Basilen Turquoise Blue P-GR, Basilen  
 20 Turquoise M-2G, Basilen Turquoise E-G, and Basilen Green E-6B, available from BASF, Sumifix Turquoise Blue G, Sumifix Turquoise Blue H-GF, Sumifix Black B, Sumifix Black H-BG, Sumifix Yellow 2GC, Sumifix Supra Scarlet 2GF, and Sumifix Brilliant Red 5BF, available from Sumitomo Chemical Company, Intracron Yellow C-  
 25 8G, Intracron Red C-8B, Intracron Turquoise Blue GE, Intracron Turquoise HA, and Intracron Black RL, avail-  
 30 able from Crompton and Knowles.

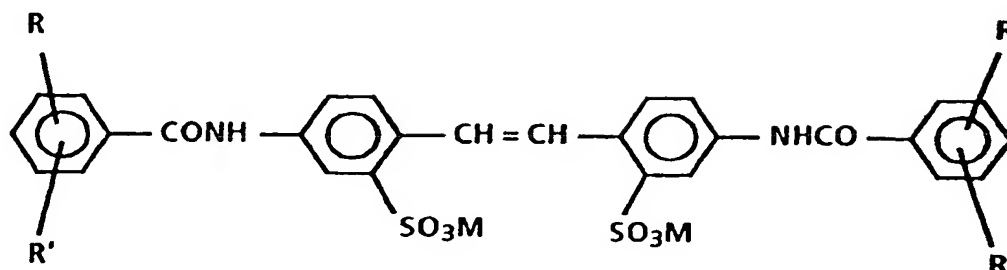
In a specific embodiment of the present invention, the dye is selected so that the polymeric particles are detectable when exposed to radiation outside the visible wavelength range. In another specific embodiment of the present invention, the dye is selected so that the polymeric particles are substantially colorless and detect-  
 25 able when exposed to radiation outside the visible wavelength range. For example, fluorescent or infrared-sen-  
 30 sitive dyes can be used provided that they exhibit sufficient solubility in water to undergo the reaction with the  
 35 polymeric micelles, they absorb light in a wavelength range other than the visible, such as infrared or ultraviolet, they emit light that is detectable by human eyes or that matches that of a suitable detector when exposed to a  
 40 spectral range outside of the visible wavelength range, and they exhibit good thermal stability and light stability. In addition, in another specific embodiment of the present invention, the ink contains both a colorant visible to  
 45 the human eye under normal conditions, such as a pigment, a dye, or particles wherein the covalently attached  
 50 dye exhibits color in the visible wavelength range, and particles wherein the covalently attached dye is detect-  
 55 able when exposed to radiation outside the visible wavelength range. In this embodiment, the covalently  
 60 attached dye can be either colored or substantially colorless. In the instance of substantially colorless dyes,  
 65 suitable dyes or chromophores are distinguishable from the visible colorant in the ink under the conditions for  
 70 viewing or detecting the ink containing substantially colorless particles. Examples of suitable fluorescent  
 75 chromophores include dansyl-Lysine, N-(2-aminoethyl)-4-amino-3,6-disulfo-1,8-dinaphthalimide dipotassium  
 80 salt, N-(2-aminopentyl)-4-amino-3,6-disulfo-1,8-dinaphthalimide dipotassium salt, Cascade Blue  
 85 ethylenediamine trisodium salt (available from Molecular Probes, Inc.), Cascade Blue cadaverine trisodium salt  
 90 (available from Molecular Probes, Inc.), bisdiazinyl derivatives of 4,4'-diaminostilbene-2,2'-disulfonic acid of the  
 95 formula



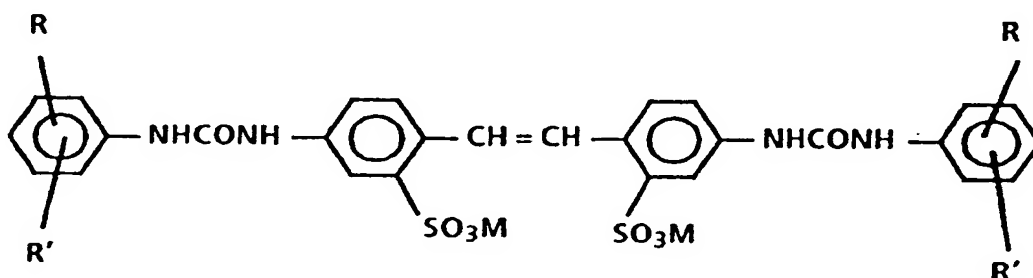
wherein R is an aromatic amine, an aliphatic amine, a hydroxyl group, an alkoxy group, an aryloxy group, a  
 100 halogen atom, an aminoalcohol group, a sulfonated aromatic amine, or the like, R' is an aromatic amine, an  
 105 aliphatic amine, a hydroxyl group, an alkoxy group, an aryloxy group, a halogen atom, an aminoalcohol group,  
 110 a sulfonated aromatic amine, or the like, M is hydrogen, a lithium ion, a sodium ion, a potassium ion, a cesium  
 115 ion, a rubidium ion, an ammonium ion, or the like, and wherein the ratio of sulfonic acid functional group to stil-  
 120 bene moiety typically varies from about 1:1 to about 6:1, although the ratio can be outside of this range; unsym-  
 125 metrical triazinyl derivatives of 4,4'-diaminostilbene-2,2'-disulfonic acid; amide derivatives of



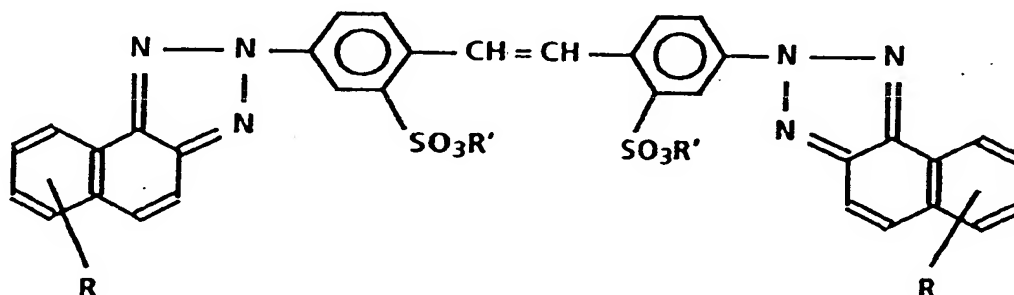
4,4'-diaminostilbene-2,2'-disulfonic acid of the formula



wherein R is alkoxy, alkyl, phenyl, hydrogen, acetyl, alkylamido, and the like, R' is hydrogen, alkyl, alkoxy, phenyl, acetyl, alkylamido, and the like, M is hydrogen, a lithium ion, a sodium ion, a potassium ion, a cesium ion, a rubidium ion, an ammonium ion, or the like, and wherein the ratio of sulfonic acid group to aminostilbene typically is from about 2:1 to about 4:1, although the ratio can be outside of this range; phenylurea derivatives of 4,4'-disubstituted stilbene-2,2'-disulfonic acid of the formula



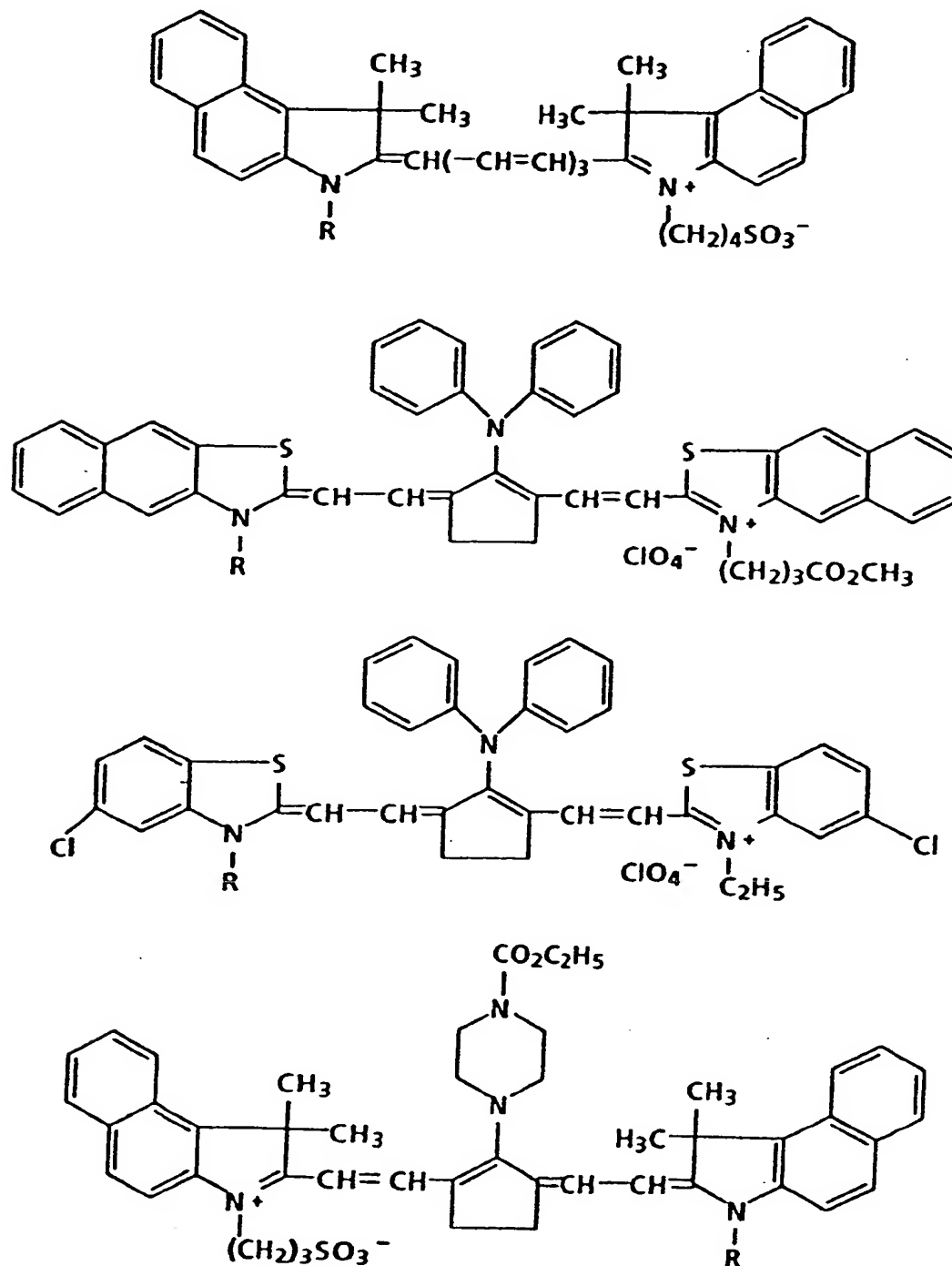
wherein R is alkoxy, alkyl, phenyl, hydrogen, acetyl, alkylamido, and the like, R' is hydrogen, alkyl, alkoxy, phenyl, acetyl, alkylamido, and the like, M is hydrogen, a lithium ion, a sodium ion, a potassium ion, a cesium ion, a rubidium ion, an ammonium ion, or the like, and the ratio of sulfonic acid group to aminostilbene typically is from about 2:1 to about 4:1, although the ratio can be outside of this range; mono- or di-naphthyltriazole derivatives of 4,4'-disubstituted stilbene disulfonic acid of the formula



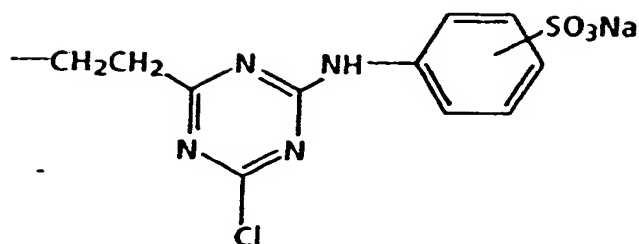
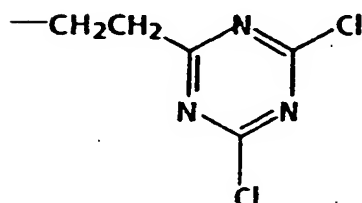
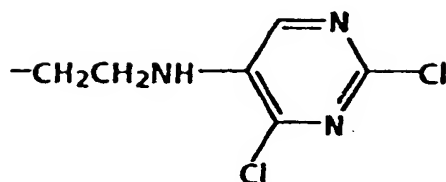
wherein R is hydrogen or  $\text{SO}_3\text{R}'$ , wherein R' is hydrogen, a lithium ion, a sodium ion, a potassium ion, a cesium ion, a rubidium ion, an ammonium ion, or the like, and wherein the ratio of sulfonic acid group to aminostilbene is typically from about 2:1 to about 4:1, although the ratio can be outside of this range; derivatives of benzothiazole; derivatives of benzoxazole; derivatives of benziminazole; derivatives of coumarin; derivatives of pyrazolines containing sulfonic acid groups; 4,4'-bis(triazin-2-ylamino)stilbene-2,2'-disulfonic acids; 2-(stilben-4-yl)naphthotriazoles; 2-(4-phenylstilben-4-yl)benzoxazoles; 4,4-bis(triazo-2-yl)stilbene-2,2'-disulfonic acids; 1,4-bis(styryl)biphenyls; 1,3-diphenyl-2-pyrazolines; bis(benzazol-2-yl) derivatives; 3-phenyl-7-(triazin-2-yl)coumarins; carbostyryls; naphthalimides; 3,7-diaminodibenzothiophen-2,8-disulfonic acid-5,5-dioxide; other commercially available materials, such as C.I. Fluorescent Brightener No. 28 (C.I. 40622), the fluorescent series Leucophor B-302, BMB (C.I. 290), BCR, BS, and the like (available from Leucophor); fluorescent

brighteners as shown in the Colour Index, volume 2, 3rd edition, (Society of Dyers and Colourists); and the like. Additional examples of suitable chromophores that absorb in the infrared region include commercially-available materials, such as the Pro-Jet IR series of materials, available from ICI Fine Chemicals Division, as well as other infrared absorbing materials.

Also suitable are the following infrared-sensitive dye structures:



wherein R can be any of the following groups:  
wherein R can be any of the following groups:



Most of the dyes with these structures are colored and thus are best suited for inks wherein the particles are both visibly colored and detectable when exposed to radiation outside the visible wavelength range.

The dyed polymeric micelles can have dye molecules attached to the micelle surfaces in any amount sufficient to impart to the micelles the desired intensity and hue of color. Typically, the dyed micelles contain the dye in an amount of from 0.03 to 20 percent by weight, preferably from 2 to 5 percent by weight. When the block copolymer micelles have silica dispersed therein, the dyed micelles typically comprise from 60 to 98 percent by weight of the block copolymer, from 1.5 to 39.5 percent by weight of silica, and from 0.5 to 20 percent by weight of the dye.

Within the ink composition, the dyed polymeric micelles are present in any effective amount to achieve the desired degree of coloration. Typically, the micelles are present in an amount of from 0.5 to 15 percent by weight, and preferably from 1 to 6 percent by weight.

The small particle size of the dyed polymeric micelles contained in the inks of the present invention enable ink compositions having many advantages of heterophase inks, such as waterfastness, lightfastness, image density, thermal stability, oxidative stability, compatibility with both coated/treated and plain papers as well as transparency materials, image edge acuity, reduced image feathering, and non-toxic and non-mutagenic properties, as well as many advantages of dye-based inks, such as transparency, stability, and long shelf life. In addition, since the particles typically are in the range of from 10 to 100 nanometers in diameter, they do not induce clogging of the printhead in an ink jet printer. Further, the dye molecules covalently bound to the

polymeric micelles generally carry ionic charges and impart stability to the particles in aqueous media via electrostatic forces. Additionally, the particulate nature of the inks and the high affinity for paper of many hydrophilic materials suitable for the A segments of the block copolymers contained in the inks, such as polyethylene oxide, further enhances the waterfastness and rub-resistance of prints made with the inks of the present invention. Inks of the present invention that are substantially colorless and detectable when exposed to radiation outside the visible wavelength range are also useful in processes wherein it is desired to place invisible markings on documents; examples of such situations include providing security markings to control the number of copies made of a document, providing invisible markings that can be detected by an imaging device and that provide instructions to the imaging device (such as instructions not to copy certain portions of the document or to alter the color of certain portions of the document), identifying the machine with which the original document was made, or the like. In addition, inks of the present invention that contain both a visible colorant, such as a pigment or a dye or visibly colored polymeric micelles, and polymeric micelles that are detectable when exposed to radiation outside the visible wavelength range can, for example, be used to identify the source of a particular ink or to provide instructions to an imaging device capable of detecting the invisible particles. Further, particles can have covalently attached thereto two or more different dyes that are visible in other wavelength regions, rendering them readable by different sensors.

Ink compositions of the present invention are suitable for use in ink jet printing processes such as continuous stream, piezoelectric drop-on-demand, bubble jet or thermal ink jet processes. Generally, the process comprises incorporating an ink of the present invention into an ink jet printing apparatus and causing droplets of the ink to be ejected in an imagewise pattern onto a suitable substrate, thereby generating images on the substrate. Any ink jet apparatus may be employed to generate images with the ink compositions disclosed herein, such as the Diablo C150 J printer, the Hewlett Packard Desk Jet printer, the Diablo C150 TJ printer, or the like. Particularly preferred is a thermal ink jet printing apparatus. The inks prepared by the process of the present invention can be used to form images on a wide variety of substrates, including plain paper such as Xerox® 4024 paper, bond paper such as Gilbert 25 percent cotton bond paper or Gilbert 100 percent cotton bond paper, silica coated papers, transparency materials, fabrics, plastics, polymeric films, and the like.

Specific embodiments of the invention will now be described in detail. These examples are intended to be illustrative, and the invention is not limited to the materials, conditions, or process parameters set forth in these embodiments. All parts and percentages are by weight unless otherwise indicated.

### EXAMPLE I

#### Cyan Ink

An ink composition was prepared as follows. To 91 milliliters of deionized water was added 1.64 grams of a polyethylene oxide-polypropylene oxide-polyethylene oxide block copolymer (Pluronic F-68, obtained from BASF) and the resulting dispersion was stirred at room temperature for 2 hours. Thereafter, 9.02 milliliters of 11.09 molar aqueous ammonium hydroxide was added to the dispersion and the mixture was stirred for an additional hour at room temperature. Subsequently, a solution of 2.0 grams of Procion Turquoise H-7G dye dissolved in 25 milliliters of water was added to the dispersion, and the mixture was stirred overnight at room temperature. The dispersion of colored polymeric micelles thus prepared was then diluted to 500 milliliters by the addition of deionized water and the excess unreacted dye was removed by ultrafiltration. The purified suspension of cyan-colored polymeric micelles was then concentrated to 85 milliliters by solvent evaporation in a rotary evaporator under reduced pressure.

To this purified concentrated suspension of cyan-colored polymeric micelles were then added 3.7 milliliters of ethylene glycol to form a cyan-colored ink composition. The cyan ink thus prepared was incorporated into a cleaned Hewlett Packard ink cartridge and jetted with a Hewlett Packard Desk Jet ink jet printer. Prints were formed on plain paper, on silica-coated paper, and on transparency material. In each instance, the cyan prints obtained exhibited solid areas of acceptable optical density (1.14 on coated paper, 0.97 on 4024 paper/felt side, 1.00 on 4024 paper/wire side, and 0.95 on transparency). Feathering was minimal on both the felt side and the wire side of the uncoated paper. In addition, the prints of the 4024 plain paper exhibited excellent waterfastness, as determined by cutting a printed solid area on 4024 paper (wire side) into two sheets, soaking one sheet in water for 2 minutes, air drying the soaked sheets, and measuring the optical densities of both the soaked and unsoaked sheets. The optical density of the sheet that was not soaked in water was 1.00 and the optical density of the sheet soaked in water for 2 minutes was 0.80. No clogging of the printhead was observed during the extensive print tests.

**EXAMPLE II****Cyan Silicated Ink**

5 An ink composition was prepared as follows. To 500 milliliters of deionized water was added 4.08 grams of a polyethylene oxide-polypropylene oxide-polyethylene oxide block copolymer (Pluronic F-68,) and the resulting dispersion was stirred at room temperature for 2 hours. Subsequently, 1.04 milliliters of tetraethoxysilane was added to the dispersion and the mixture was stirred vigorously with a magnetic stirrer for 1 hour. Thereafter, 22.5 milliliters of 11.09 molar aqueous ammonium hydroxide was added to the dispersion and the mixture  
 10 was stirred for one hour at room temperature. A solution of 2.0 grams of ProcionTurquoise H-7G dye dissolved in 25 milliliters of water was then added to 100 milliliters of the dispersion of silicated micelles, and the mixture was stirred overnight at room temperature. The excess unreacted dye was then removed from the dispersion of colored silicated polymeric micelles by ultrafiltration. The purified suspension of cyan polymeric micelles was then concentrated to 100 milliliters by evaporation of the solvent in a Rotary evaporator at a reduced pressure  
 15 of about 20 mm Hg. The particle size as determined by transmission electron microscopy (TEM) was about 20 nanometers. The particle size prior to addition of the dye as determined by (TEM) was about 20 nanometers, indicating that coloration of the particles does not affect their size as determined within the limitations of the measurement technique.

Subsequently, 50 milliliters of the purified suspension of cyan colored polymeric micelles was concentrated  
 20 to a volume of 9 milliliters under a reduced pressure of approximately 20 mm Hg by use of a rotary evaporator. To this darkly colored cyan suspension were then added 2.42 milliliters of ethylene glycol and 4.1 milliliters of water to form a cyan ink composition.

The cyan ink thus prepared was incorporated into a cleaned Hewlett Packard ink cartridge and jetted with a Hewlett Packard Desk Jet ink jet printer. Prints were formed on plain paper and on silica-coated paper. In  
 25 each instance, the cyan prints obtained exhibited solid areas of acceptable optical density (1.37 on coated paper, 0.98 on 4024 paper/felt side, and 0.94 on 4024 paper/wire side). Feathering was minimal on both the felt side and the wireside of the uncoated paper. In addition, the prints of the 4024 plain paper exhibited excellent waterfastness, as determined by cutting a printed solid area on 4024 paper (wire side) into two sheets, soaking one sheet in water for 2 minutes, air drying the soaked sheets, and measuring the optical densities of both the  
 30 soaked and unsoaked sheets. The optical density of the sheet that was not soaked in water was 0.94 and the optical density of the sheet soaked in water for 2 minutes was 0.80. No clogging of the printhead was observed during the extensive print tests.

**EXAMPLE III****Yellow Ink**

35 An ink composition was prepared as follows. To 91 milliliters of deionized water was added 1.64 grams of a polyethylene oxide-polypropylene oxide-polyethylene oxide block copolymer (Pluronic F-68) and the resulting dispersion was stirred at room temperature for 2 hours. Thereafter, 9.02 milliliters of 11.09 molar aqueous ammonium hydroxide was added to the dispersion and the mixture was stirred for an additional hour at room temperature. Subsequently, a solution of 4.0 grams of Procion Yellow MX-8G dye dissolved in 25 milliliters of water was added to the dispersion, and the mixture was stirred overnight at room temperature. The dispersion of colored polymeric micelles thus prepared was then diluted to 500 milliliters by the addition of deionized water  
 40 and the excess unreacted dye was removed by ultrafiltration. The purified suspension of yellow polymeric micelles was then concentrated to 85 milliliters by solvent evaporation in a rotary evaporator under reduced pressure.

To this purified concentrated suspension of yellow polymeric micelles were then added 3.7 milliliters of ethylene glycol to form a yellow ink composition. The yellow ink thus prepared was tested as described in examples I & II. The yellow prints obtained exhibited solid areas of acceptable optical density (0.84 on coated paper,  
 50 0.66 on 4024 paper/felt side, 0.65 on 4024 paper/wire side, and 0.58 on transparency). Feathering was minimal on both the felt side and the wire side of the uncoated paper. In addition, the prints of the 4024 plain paper exhibited excellent waterfastness, as determined by cutting a printed solid area on 4024 paper (wire side) into two sheets, soaking one sheet in water for 2 minutes, air drying the soaked sheets, and measuring the optical densities of both the soaked and unsoaked sheets. The optical density of the sheet that was not soaked in water  
 55 was 0.84 and the optical density of the sheet soaked in water for 2 minutes was 0.71. No clogging of the printhead was observed during the extensive print tests.

**EXAMPLE IV****Magenta Silicated Ink**

5 An ink composition was prepared as follows. To 500 milliliters of deionized water was added 4.08 grams of a polyethylene oxide-polypropylene oxide-polyethylene oxide block copolymer (Pluronic F-68,) and the resulting dispersion was stirred at room temperature for 2 hours. Subsequently, 1.04 milliliters of tetraethoxysilane was added to the dispersion and the mixture was stirred vigorously with a magnetic stirrer for 1 hour. Thereafter, 22.5 milliliters of 11.09 molar aqueous ammonium hydroxide was added to the dispersion and the mixture  
10 was stirred for one hour at room temperature. A solution of 3.0 grams of Levafix Brilliant Red EGBA dye dissolved in 25 milliliters of water was then added to 100 milliliters of the dispersion of silicated micelles, and the mixture was stirred overnight at room temperature. The excess unreacted dye was then removed from the dispersion of colored silicated polymeric micelles by ultrafiltration. The purified suspension of magenta polymeric micelles was then concentrated to 100 milliliters by evaporation of the solvent in a rotary evaporator at a reduced  
15 pressure of about 20 mm Hg. The particle size was about 20 nm. The particle size prior to addition of the dye as determined by TEM was about 20 nm, indicating that coloration of the particles did not affect their size as determined within the limitations of the measurement technique.

Subsequently, 50 milliliters of the purified suspension of magenta polymeric micelles was concentrated to a volume of 9 milliliters under a reduced pressure of approximately 20 mm Hg by use of a rotary evaporator.  
20 To this darkly colored magenta suspension were then added 2.42 milliliters of ethylene glycol and 4.1 milliliters of water to form a magenta colored ink composition.

The magenta ink thus prepared was tested as above. The magenta prints obtained exhibited solid areas of acceptable optical density (1.02 on coated paper, 0.86 on 4024 paper/felt side, and 0.92 on 4024 paper/wire side). Feathering was minimal on both the felt side and the wire side of the uncoated paper. In addition, the  
25 prints of the 4024 plain paper exhibited excellent waterfastness, as determined by cutting a printed solid area on 4024 paper (wire side) into two sheets, soaking one sheet in water for 2 minutes, air drying the soaked sheets, and measuring the optical densities of both the soaked and unsoaked sheets. The optical density of the sheet that was not soaked in water was 0.92 and the optical density of the sheet soaked in water for 2 minutes was 0.78. No clogging of the printhead was observed during the extensive print tests.

**EXAMPLE V****Black Silicated Ink**

35 An ink composition was prepared as follows. To 500 milliliters of deionized water was added 4.08 grams of a polyethylene oxide-polypropylene oxide-polyethylene oxide block copolymer (Pluronic F-68,) and the resulting dispersion was stirred at room temperature for 2 hours. Subsequently, 1.04 milliliters of tetraethoxysilane was added to the dispersion and the mixture was stirred vigorously with a magnetic stirrer for 1 hour. Thereafter, 22.5 milliliters of 11.09 Molar aqueous ammonium hydroxide was added to the dispersion and the mixture  
40 was stirred for one hour at room temperature. A solution of 2.0 grams of Duasyn Black RL-SF dye dissolved in 25 milliliters of water was then added to 100 milliliters of the dispersion of silicated micelles, and the mixture was stirred overnight at room temperature. The excess unreacted dye was then removed from the dispersion of black silicated polymeric micelles by ultrafiltration. The purified suspension of black polymeric micelles was then concentrated to 100 milliliters by evaporation of the solvent in a rotary evaporator at a reduced pressure  
45 of about 20 mm Hg. The particle size was about 20 nanometers. The particle size prior to addition of the dye as determined by TEM was about 20 nanometers, indicating that coloration of the particles did not affect their size as determined within the limitations of the measurement technique.

Subsequently, 50 milliliters of the purified suspension of black polymeric micelles was concentrated to a volume of 9 milliliters under a reduced pressure of approximately 20 mm Hg by use of a rotary evaporator. To  
50 this black suspension were then added 2.42 milliliters of ethylene glycol and 4.1 milliliters of water to form a black ink composition.

The black ink thus prepared was tested as above. The black prints obtained exhibited solid areas of acceptable optical density (1.22 on coated paper, 1.02 on 4024 paper/felt side, and 0.98 on 4024 paper/wire side). Feathering was minimal on both the felt side and the wire side of the uncoated paper. In addition, the prints of  
55 the 4024 plain paper exhibited excellent waterfastness, as determined by cutting a printed solid area on 4024 paper (wire side) into two sheets, soaking one sheet in water for 2 minutes, air drying the soaked sheets, and measuring the optical densities of both the soaked and unsoaked sheets. The optical density of the sheet that was not soaked in water was 1.22 and the optical density of the sheet soaked in water for 2 minutes was 1.04.

No clogging of the printhead was observed during the extensive print tests.

#### **EXAMPLE VI**

##### **Black Silicated Ink**

An ink composition was prepared as follows. To 675 milliliters of deionized water was added 12.2 grams of a polyethylene oxide-polypropylene oxide-polyethylene oxide block copolymer (Pluronic F-38 and the resulting dispersion was stirred at room temperature for 2 hours. Subsequently, 3.1 milliliters of tetraethoxysilane was added to the dispersion and the mixture was stirred vigorously with a magnetic stirrer for 1 hour. Thereafter, 67.5 milliliters of 10.89 molar aqueous ammonium hydroxide was added to the dispersion and the mixture was stirred for one hour at room temperature. A solution of 1.04 grams of Basilen PBR Black RL-SF dye dissolved in 25 milliliters of water was then added to 100 milliliters of the dispersion of silicated micelles, and the mixture was stirred overnight at room temperature. The excess unreacted dye was then removed from the dispersion of black silicated polymeric micelles by ultrafiltration. The purified suspension of black polymeric micelles was then concentrated to 100 milliliters by evaporation of the solvent in a rotary evaporator at a reduced pressure of about 20 mm Hg. The concentrated suspension was freeze dried to yield 0.8 gram of a black powder. The particle size was about 80 nanometers.

Subsequently, a black ink composition was prepared by suspending by sonication for 2 minutes in an ultrasonic bath 0.5 gram of this black powder into a solution made of 25 milliliters of water and 4 milliliters of ethylene glycol to form a black ink composition.

The black ink thus prepared was tested as above. The black prints obtained exhibited solid areas of acceptable optical density (1.42 on coated paper, 1.25 on 4024 paper/felt side, and 0.88 on 4024 paper/wire side). Feathering was minimal on both the felt side and the wire side of the uncoated paper. In addition, the prints of the 4024 plain paper exhibited excellent waterfastness, as determined by cutting a printed solid area on 4024 paper (wire side) into two sheets, soaking one sheet in water for 2 minutes, air drying the soaked sheets, and measuring the optical densities of both the soaked and unsoaked sheets. The optical density of the sheet that was not soaked in water was 1.42 and the optical density of the sheet soaked in water for 2 minutes was 1.14. No clogging of the printhead was observed during the extensive print tests.

#### **EXAMPLE VII**

##### **Black Silicated Ink**

An ink composition was prepared as follows. To 675 milliliters of deionized water was added 12.2 grams of a polyethylene oxide-polypropylene oxide-polyethylene oxide block copolymer (Pluronic F-108) and the resulting dispersion was stirred at room temperature for 2 hours. Subsequently, 3.1 milliliters of tetraethoxysilane was added to the dispersion and the mixture was stirred vigorously with a magnetic stirrer for 1 hour. Thereafter, 67.5 milliliters of 10.89 molar aqueous ammonium hydroxide was added to the dispersion and the mixture was stirred for one hour at room temperature. A solution of 1.04 grams of Basilen PBR Black RL-SF dye dissolved in 25 milliliters of water was then added to 100 milliliters of the dispersion of silicated micelles, and the mixture was stirred overnight at room temperature. The excess unreacted dye was then removed. The purified suspension of black polymeric micelles was then concentrated to 100 milliliters by evaporation. The concentrated suspension was freeze-dried to yield 0.68 gram of a black powder. The particle size was about 30 nanometers.

Subsequently a black ink composition was prepared by suspending by sonication for 2 minutes in an ultrasonic bath 0.5 gram of this black powder into a solution made of 25 milliliters of water and 4 milliliters of ethylene glycol to form a black colored ink composition.

The black ink thus prepared was tested as above. The black prints obtained exhibited solid areas of acceptable optical density (1.36 on coated paper, 1.15 on 4024 paper/felt side, and 0.98 on 4024 paper/wire side). Feathering was minimal on both the felt side and the wire side of the uncoated paper. In addition, the prints of the 4024 plain paper exhibited excellent waterfastness, as determined by cutting a printed solid area on 4024 paper (wire side) into two sheets, soaking one sheet in water for 2 minutes, air drying the soaked sheets, and measuring the optical densities of both the soaked and unsoaked sheets. The optical density of the sheet that was not soaked in water was 1.36 and the optical density of the sheet soaked in water for 2 minutes was 1.31. No clogging of the printhead was observed during the extensive print tests.



**EXAMPLE VIII****Black Silicated Ink**

5 An ink composition was prepared as follows. To 675 milliliters of deionized water was added 12.2 grams of a polyethylene oxide-polypropylene oxide-polyethylene oxide block copolymer (Pluronic F-127) and the resulting dispersion was stirred at room temperature for 2 hours. Subsequently, 3.1 milliliters of tetraethoxysilane was added to the dispersion and the mixture was stirred vigorously with a magnetic stirrer for 1 hour. Thereafter, 67.5 milliliters of 10.89 molar aqueous ammonium hydroxide was added to the dispersion and the mixture  
10 was stirred for one hour at room temperature. A solution of 1.04 grams of Basilen PBR Black RL-SF dye dissolved in 25 milliliters of water was then added to 100 milliliters of the dispersion of silicated micelles, and the mixture was stirred overnight at room temperature. The excess unreacted dye was then removed. The purified suspension of black polymeric micelles was then concentrated to 100 milliliters by evaporation. The concentrated suspension was freeze-dried to yield 0.75 gram of a black powder. The particle size was about 70  
15 nanometers.

Subsequently, a black ink composition was prepared by suspending by sonication for 2 minutes in an ultrasonic bath 0.5 gram of this black powder into a solution made of 25 milliliters of water and 4 milliliters of ethylene glycol to form a black ink composition.

The black ink thus prepared was tested as above. The black prints obtained exhibited solid areas of acceptable optical density ( 1.16 on coated paper, 1.25 on 4024 paper/felt side, and 1.08 on 4024 paper/wire side).  
20 Feathering was minimal on both the felt side and the wire side of the uncoated paper. In addition, the prints of the 4024 plain paper exhibited excellent waterfastness; as determined by cutting a printed solid area on 4024 paper (wire side) into two sheets, soaking one sheet in water for 2 minutes, air drying the soaked sheets, and measuring the optical densities of both the soaked and unsoaked sheets. The optical density of the sheet that  
25 was not soaked in water was 1.16 and the optical density of the sheet soaked in water for 2 minutes was 1.01. No clogging of the printhead was observed during the extensive print tests.

**EXAMPLE IX****Black Silicated Ink**

An ink composition was prepared as follows. To 675 milliliters of deionized water was added 12.2 grams of a polyethylene oxide-polypropylene oxide-polyethylene oxide block copolymer (Pluronic F-68) and the resulting dispersion was stirred at room temperature for 2 hours. Subsequently, 3.1 milliliters of tetraethoxysilane was added to the dispersion and the mixture was stirred vigorously with a magnetic stirrer for 1 hour. Thereafter, 67.5 milliliters of 10.89 molar aqueous ammonium hydroxide was added to the dispersion and the mixture  
35 was stirred for one hour at room temperature. A solution of 1.10 grams of Basilen PBR Black RL-SF dye and of 0.90 gram of Reactive Orange 16 dye dissolved in 50 milliliters of water was then added to 200 milliliters of the dispersion of silicated micelles, and the mixture was stirred overnight at room temperature. The excess unreacted dyes were then removed. The purified suspension of black colored polymeric micelles was then concentrated to 100 milliliters by evaporation. The concentrated suspension was freeze-dried to yield 0.75 gram  
40 of a deeply black powder. The particle size was about 25 nanometers.

Subsequently, a black ink composition was prepared by suspending by sonication for 2 minutes in an ultrasonic bath 0.5 gram of this black powder into a solution made of 25 milliliters of water and 4 milliliters of ethylene glycol to form a black ink composition.  
45

The black ink thus prepared was tested as above. The black prints obtained exhibited solid areas of acceptable optical density (1.54 on coated paper, 1.48 on 4024 paper/felt side, and 1.38 on 4024 paper/wire side). Feathering was minimal on both the felt side and the wire side of the uncoated paper. In addition, the prints of the 4024 plain paper exhibited excellent waterfastness, as determined by cutting a printed solid area on 4024  
50 paper (wire side) into two sheets, soaking one sheet in water for 2 minutes, air drying the soaked sheets, and measuring the optical densities of both the soaked and unsoaked sheets. The optical density of the sheet that was not soaked in water was 1.46 and the optical density of the sheet soaked in water for 2 minutes was 1.31. No clogging of the printhead was observed during the extensive print tests.

**EXAMPLE X****Black Silicated Ink**

5 To 675 milliliters of deionized water was added 12.2 grams of a polyethylene oxide-polypropylene oxide-polyethylene oxide block copolymer (Pluronic F-68) and the resulting dispersion was stirred at room temperature for 2 hours. Subsequently, 3.1 milliliters of tetraethoxysilane was added to the dispersion and the mixture was stirred vigorously with a magnetic stirrer for 1 hour. Thereafter, 67.5 milliliters of 10.89 molar aqueous ammonium hydroxide was added to the dispersion and the mixture was stirred for one hour at room temperature.

10 A solution of 2.0 grams of Basilen PBR Black RL-SF dye dissolved in 50 milliliters of water was then added to 100 milliliters of the dispersion of silicated micelles, and the mixture was stirred overnight at room temperature. The excess unreacted dye was then removed. The purified suspension of black polymeric micelles was then concentrated to 100 milliliters by evaporation. The concentrated suspension was freeze-dried to yield 0.83 gram of a deeply black powder. The particle size was about 25 nanometers.

15 A solution of 2.0 grams of Reactive Orange dye dissolved in 50 milliliters of water was then added to 100 milliliters of the dispersion of silicated micelles, and the mixture was stirred overnight at room temperature. The excess unreacted dye was then removed. The purified suspension of orange colored polymeric micelles was then concentrated to 100 milliliters by evaporation. The concentrated suspension was freeze-dried to yield 0.68 gram of an orange powder. The particle size was about 25 nanometers.

20 Subsequently, a black ink composition was prepared by suspending by sonication for 2 minutes in an ultrasonic bath 0.25 gram of the black powder and 0.30 gram of the orange powder into a solution made of 25 milliliters of water and 4 milliliters of ethylene glycol to form a deep black ink composition.

The black ink thus prepared was tested as above. The black prints obtained exhibited solid areas of acceptable optical density (1.52 on coated paper, 1.44 on 4024 paper/felt side, and 1.28 on 4024 paper/wire side). Feathering was minimal on both the felt side and the wire side of the uncoated paper. In addition, the prints of the 4024 plain paper exhibited excellent waterfastness, as determined by cutting a printed solid area on 4024 paper (wire side) into two sheets, soaking one sheet in water for 2 minutes, air drying the soaked sheets, and measuring the optical densities of both the soaked and unsoaked sheets. The optical density of the sheet that was not soaked in water was 1.37 and the optical density of the sheet soaked in water for 2 minutes was 1.

30 15. No clogging of the printhead was observed during the extensive print tests.

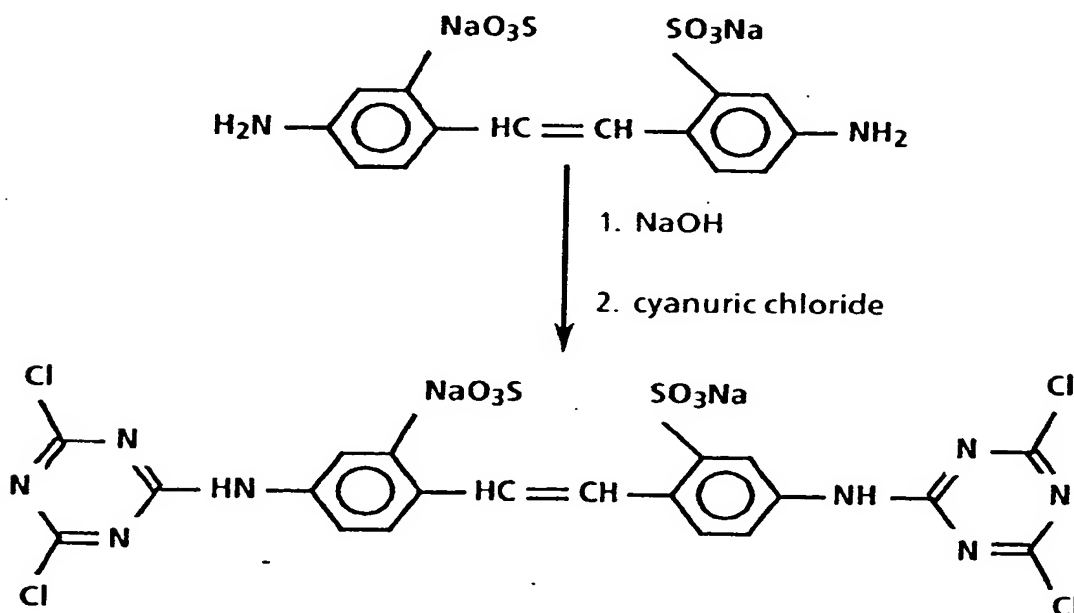
**EXAMPLE XI****Red Ink**

35 To 91 milliliters of deionized water was added 1.64 grams of a polyethylene oxide-polypropylene oxide-polyethylene oxide block copolymer (Pluronic F-68) and the resulting dispersion was stirred at room temperature for 2 hours. Thereafter, 9.02 milliliters of 11.09 molar aqueous ammonium hydroxide was added to the dispersion and the mixture was stirred for an additional hour at room temperature. Subsequently, a solution of 3.0 grams of Procion Yellow MX-8G dye and 2.5 grams of Levafix Brilliant Red EGBA dissolved in 40 milliliters of water was added to the dispersion, and the mixture was stirred overnight at room temperature. The dispersion of colored polymeric micelles thus prepared was then diluted to 500 milliliters by the addition of deionized water and the excess unreacted dye was removed. The purified suspension of red polymeric micelles was then concentrated to 85 milliliters by solvent evaporation.

45 To this purified concentrated suspension of red polymeric micelles were then added 3.7 milliliters of ethylene glycol to form a red ink composition. The red ink thus prepared was tested as above. The red prints obtained exhibited solid areas of acceptable optical density (1.09 on coated paper, 1.02 on 4024 paper/felt side, 0.65 on 4024 paper/wire side, and 0.98 on transparency). Feathering was minimal on both the felt side and the wire side of the uncoated paper. In addition, the prints of the 4024 plain paper exhibited excellent waterfastness, as determined by cutting a printed solid area on 4024 paper (wire side) into two sheets, soaking one sheet in water for 2 minutes, air drying the soaked sheets, and measuring the optical densities of both the soaked and unsoaked sheets. The optical density of the sheet that was not soaked in water was 1.02 and the optical density of the sheet soaked in water for 2 minutes was 0.85. No clogging of the printhead was observed during the extensive print tests.

**EXAMPLE XII****Fluorescent Silicated Ink****A. Preparation of a Reactive Fluorescent Dye**

A solution of cyanuric chloride (9.96 grams, 54 millimoles) in acetone (50 milliliters) was added to vigorously stirred water (500 milliliters) at 5°C. To the resulting finely-dispersed suspension was added dropwise a solution of 4,4'-diaminostilbene-2,2'-disulfonic acid, disodium salt (10.0 grams, 127 millimoles, prepared from 4,4'-diaminostilbene-2,2'-disulfonic acid (10.0 g) and sodium hydroxide (2.174 grams) in water (250 milliliters)). The temperature of the reaction mixture was maintained at 5°C throughout the addition. The pH of the reaction mixture was maintained at a value higher than 2 by portionwise addition of Na<sub>2</sub>CO<sub>3</sub> (total amount added 4.08 grams). At the end of the addition, the reaction mixture was stirred at 5°C for 30 minutes. Subsequently, sodium chloride (100 grams) was added to the mixture. The resulting solid was separated by filtration, washed with acetone, and dried *in vacuo* at 50°C overnight to yield 15.7 grams of the product. The reaction scheme was as follows:

**B. Preparation of Silicated Fluorescent Particles**

To 1350 milliliters of deionized water was added 24.4 grams of a polyethylene oxide-polypropylene oxide-polyethylene oxide block copolymer (Pluronic F-68) and 6.2 milliliters of tetraethoxysilane, and the resulting dispersion was stirred vigorously at room temperature for 2 hours. Thereafter, 135 milliliters of 11 molar aqueous ammonium hydroxide was added to the mixture and the mixture was stirred overnight at room temperature. Subsequently, a suspension of 1.0 gram of 4,4'-di-(4',6'-dichloro-2,4,6-triazin-2-yl)-aminostilbene-2,2'-disulfonic acid, disodium salt in 12.5 milliliters of water prepared as described in paragraph (A) of this Example was added to a 100 milliliter aliquot of the mixture containing the silicated aggregates, and the resulting mixture was stirred overnight at room temperature. Excess unreacted dye was removed. The purified mixture was concentrated to 30 milliliters by evaporation.

**C. Preparation of a Fluorescent Ink**

An ink composition was prepared by adding 1 milliliter of ethylene glycol to 9 milliliters of the slightly-yellow highly-fluorescent solution obtained in paragraph (B) of this Example. The resulting solution was filtered through a 0.45  $\mu\text{m}$  filter to obtain an ink.

**D. Printing Tests**

The ink prepared as described in paragraph (C) of this Example was tested as above. The prints obtained were invisible to the eye but were strongly fluorescent when examined under ultraviolet lamps emitting at either 254 or 366 nanometers. Extremely high contrast was observed for images printed on the bond paper (non-fluorescent paper). The contrast was lower for the images on the 4024 paper, which contains a fluorescent brightener, but the images were easily detectable. No feathering of the prints was observed on either the felt or the wire sides of the papers. Prints on both papers exhibited very high waterfastness, as exemplified by the following test: a printed solid area was cut in two parts, and one half was soaked in water for 2 minutes and subsequently air dried. The fluorescence emissions from both halves were measured with a SPEX fluorescence spectrometer. No decrease in fluorescence intensity was detected in the washed half compared to the untreated half.

**EXAMPLE XIII****Colored Inks Containing Fluorescent Silicated Particles****A. Preparation of Silicated Fluorescent Particles**

To 1350 milliliters of deionized water was added 24.4 grams of a polyethylene oxide-polypropylene oxide-polyethylene oxide block copolymer (Pluronic F-68) and 6.2 milliliters of tetraethoxysilane, and the resulting dispersion was stirred vigorously at room temperature for 2 hours. Thereafter, 135 milliliters of 11 molar aqueous ammonium hydroxide was added to the mixture, and the mixture was stirred overnight at room temperature. Subsequently, a suspension of 8.0 grams of 4,4'-di-(4'',6''-dichloro-2,4,6-triazin-2-yl)-aminostilbene-2,2'-disulfonic acid, disodium salt in 100 milliliters of water prepared as described in paragraph (A) of Example XII was added to an 800 milliliter aliquot of the mixture containing the silicated aggregates, and the resulting mixture was stirred overnight at room temperature. Excess unreacted dye was removed by ultrafiltration, and the fluorescent particles were isolated by freeze drying, resulting in a slightly-yellow highly-fluorescent free-flowing powder (11.8 grams, containing about 9.5 percent by weight of the fluorescent dye, from UV absorption at 342 nanometers, using 4,4'-diaminostilbene-2,2'-disulfonic acid, disodium salt as a model compound).

**B. Preparation of a Magenta Ink Containing Silicated Fluorescent Particles**

A magenta ink was prepared by mixing together 35.0 grams of Projet Magenta dye, 0.51 gram of pyrazole, 1.07 grams of Discole N-506, and 69.53 grams of distilled water. To 9.0 milliliters of this ink was added 0.50 gram of the fluorescent particles prepared as described in paragraph (A) of this Example, and the resulting mixture was stirred for two hours and then filtered through a 0.45  $\mu$ m filter, resulting in a magenta ink containing fluorescent particles. For comparative purposes, a magenta ink of identical composition, except that it contained no fluorescent particles, was also prepared.

**C. Preparation of a Cyan Ink Containing Silicated Fluorescent Particles**

A cyan ink was prepared by mixing together 30.03 grams of Projet Cyan dye, 0.46 gram of pyrazole, 1.0 gram of Discole N-506, and 65.6 grams of distilled water. To 9.0 milliliters of this ink was added 0.50 gram of the fluorescent particles prepared as described in paragraph (A) of this Example, and the resulting mixture was stirred for two hours and then filtered through a 0.45  $\mu$ m filter, resulting in a cyan ink containing fluorescent particles. For comparative purposes, a cyan ink of identical composition, except that it contained no fluorescent particles, was also prepared.

**D. Printing Tests**

The inks prepared as described in paragraphs (B) and (C) of this Example were incorporated into a cleaned Hewlett Packard ink cartridge and jetted with a Hewlett Packard Desk Jet printer and prints were made on Strathmore writing bond paper (25 percent cotton fiber), and on Fuji Xerox L. paper. Under normal lighting conditions, the prints made with inks containing no fluorescent particles did not differ significantly from the prints made with inks of the same color containing no fluorescent particles, indicating that the fluorescent particles had no deleterious effect on print quality. When observed under ultraviolet light emitted at either 254 nanometers or at 366 nanometers, however, the prints made with inks containing the fluorescent particles were highly

fluorescent, while the prints made with inks of the same color containing no fluorescent particles did not fluoresce at all. These results demonstrate that it is possible to detect the fluorescence of the tagged particles in the presence of large amounts of dyes. Extremely high contrast was observed for the fluorescent images. The prints made with inks containing the fluorescent particles also exhibited very high waterfastness, as exemplified by the following test: a printed solid area was cut in two parts, and one half was soaked in water for 2 minutes and subsequently air dried. The fluorescence emissions from both halves were measured with a SPEX fluorescence spectrometer and the optical density of both halves was measured with a Macbeth TR927 Densitometer. The results were as follows:

Ink	Optical Density			Fluorescence Intensity		
	Before Wash	After Wash	% Residual	Before Wash	After Wash	% Residual
Magenta Fluorescent	0.87	0.43	33	$1.9 \times 10^5$	$4.8 \times 10^5$	152.6
Magenta Nonfluorescent	1.27	0.42	49	0	0	---
Cyan Fluorescent	1.00	0.56	56	$1.2 \times 10^5$	$6.5 \times 10^5$	441.7
Cyan Nonfluorescent	1.12	0.61	54	0	0	---

#### EXAMPLE XIV

##### Fluorescent Ink

##### A. Preparation of Fluorescent Particles

To 1350 milliliters of deionized water was added 24.4 grams of a polyethylene oxidepolypropylene oxide-polyethylene oxide block copolymer (Pluronic F-68) and the resulting dispersion was stirred vigorously at room temperature for 2 hours. Thereafter, 135 milliliters of 11 molar aqueous ammonium hydroxide was added to the mixture and the mixture was stirred overnight at room temperature. Subsequently, a suspension of 1.0 gram of 4,4'-di-(4",6"-dichloro-2,4,6-triazin-2-yl)-aminostilbene-2,2'-disulfonic acid, disodium salt in 12.5 milliliters of water prepared as described in paragraph (A) of Example XII was added to a 100 milliliter aliquot of the mixture containing the aggregates, and the resulting mixture was stirred overnight at room temperature. Excess unreacted dye was removed. The purified mixture was concentrated to 30 milliliters by evaporation.

##### B. Preparation of a Fluorescent Ink

An ink composition was prepared by adding 1 milliliter of ethylene glycol to 9 milliliters of the slightly-yellow highly-fluorescent solution obtained in paragraph (A) of this Example. The resulting solution was filtered through a 0.45  $\mu$ m filter to obtain an ink.

##### C Printing Tests

The ink prepared as described in paragraph (B) of this Example was tested as described in example X III. The prints obtained were invisible to the eye but were strongly fluorescent when examined under ultraviolet lamps emitting at either 254 nanometers or 366 nanometers. Extremely high contrast was observed for images printed on the bond paper (non-fluorescent paper). The contrast was lower for the images on the 4024 paper, which contains a fluorescent brightener, but the images were easily detectable. No feathering of the prints was observed on either the felt or the wire sides of the papers. Prints on both papers exhibited very high waterfastness, as exemplified by the following test: a printed solid area was cut in two parts, and one half was soaked

in water for 2 minutes and subsequently air dried. The fluorescence emissions from both halves were measured with a SPEX fluorescence spectrometer. No decrease in fluorescence intensity was detected in the washed half compared to the untreated half.

## 5 **EXAMPLE XV**

### **Fluorescent Ink**

#### **A. Preparation of Fluorescent Particles**

10 To 1350 milliliters of deionized water was added 24.4 grams of a polyethylene oxide-polypropylene oxide-polyethylene oxide block copolymer (Pluronic F-68) and the resulting dispersion was stirred vigorously at room temperature for 2 hours. Thereafter, 135 milliliters of 11 molar aqueous ammonium hydroxide was added to the mixture and the mixture was stirred overnight at room temperature. Subsequently, a suspension of 8.0  
15 grams of 4,4'-di-(4",6'-dichloro-2,4,6-triazin-2-yl)-aminostilbene-2,2'-disulfonic acid, disodium salt in 100 milliliters of water prepared as described in paragraph (A) of Example XII was added to an 800 milliliter aliquot of the mixture containing the aggregates, and the resulting mixture was stirred overnight at room temperature. Excess unreacted dye was removed, and the fluorescent particles were isolated by freeze drying, resulting in a slightly-yellow highly-fluorescent free-flowing powder (10.2 grams, containing about 10.2 percent by weight  
20 of the fluorescent dye, from UV absorption at 342 nanometers, using 4,4'-diaminostilbene-2,2'-disulfonic acid, disodium salt as a model compound).

#### **B. Preparation of a Magenta Ink Containing Fluorescent Particles**

25 A magenta ink was prepared by mixing together 35.0 grams of Projet Magenta dye, 0-51 gram of pyrazole, 1.07 grams of Discole N-506, and 69.53 grams of distilled waster. To 9.0 milliliters of this ink was added 0.50 grams of the fluorescent particles prepared as described in paragraph (A) of this Example, and the resulting mixture was stirred for two hours and then filtered through a 0.45  $\mu$ m filter, resulting in a magenta ink containing fluorescent particles. For comparative purposes, a magenta ink of identical composition, except that it contained  
30 no fluorescent particles, was also prepared.

#### **C. Printing Tests**

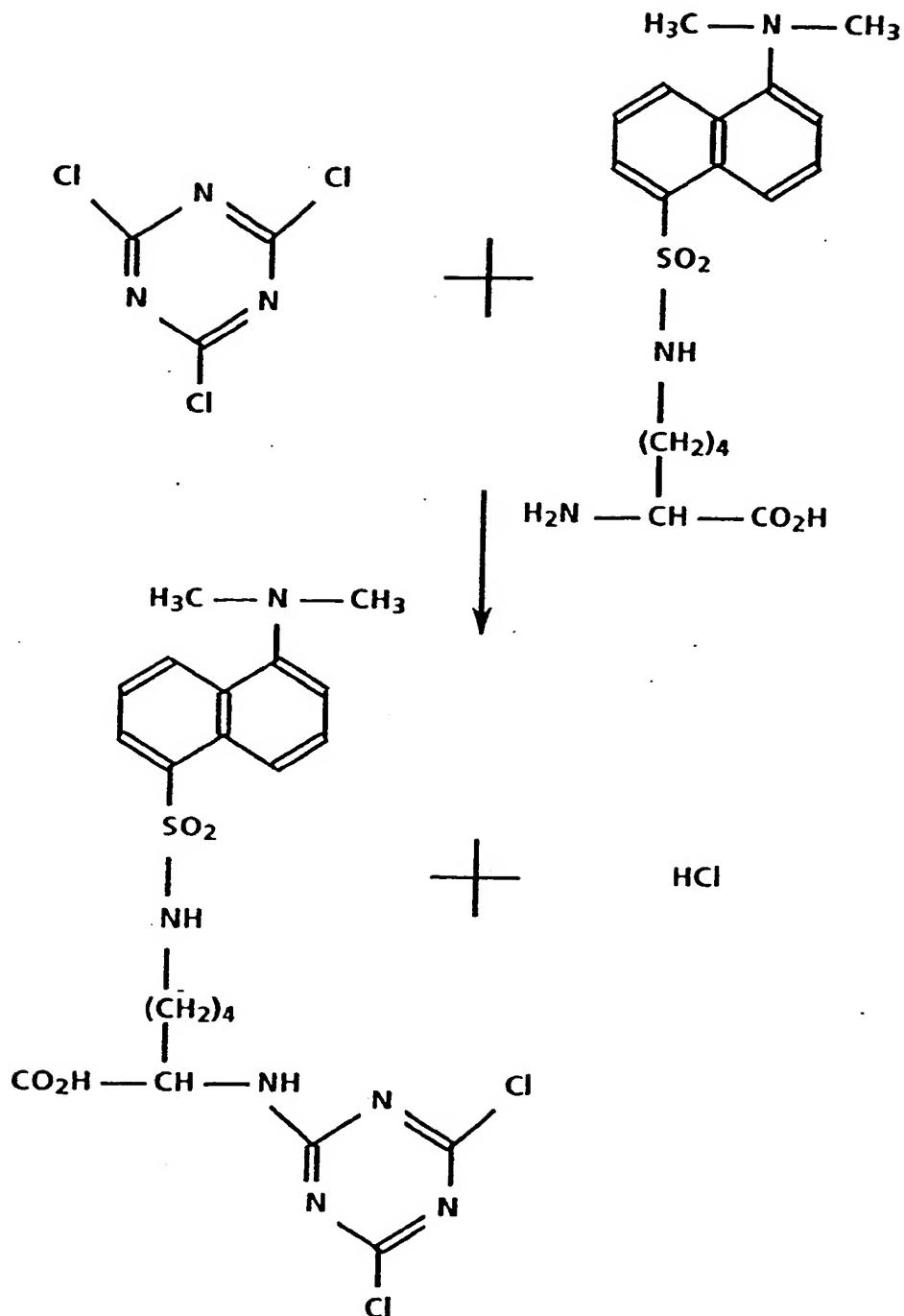
35 The ink prepared as described in paragraph (B) of this Example was tested as described above. Under normal lighting conditions, the prints made with inks containing the fluorescent particles did not differ significantly from the prints made with a magenta ink containing no fluorescent particles, indicating that the fluorescent particles had no deleterious effect on print quality. When observed under ultraviolet light emitted at either 254 nanometers or at 366 nanometers, however, the prints made with the ink containing the fluorescent particles were highly fluorescent, while the prints made with inks of the same color containing no fluorescent particles  
40 did not fluoresce at all. These results demonstrate that it is possible to detect the fluorescence of the tagged particles in the presence of large amounts of dyes. Extremely high contrast and waterfastness were observed for the fluorescent images.

## 45 **EXAMPLE XVI**

### **Fluorescent Silicated Ink**

#### **A. Preparation of a Reactive Fluorescent Dye**

50 A solution of cyanuric chloride (0.54 grams 2.9 millimoles in acetone (3 milliliters) was added to vigorously stirred water (100 milliliters) containing sodium carbonate (0.62 gram, 5.85 millimoles, dansyl lysine (1.003 grams, 2.64 millimoles, and sodium hydroxide (0.2 gram) at 5°C. The temperature of the reaction mixture was maintained at 5°C throughout the addition. At the end of the addition, the reaction mixture was stirred at 5°C for two hours. Subsequently, the reaction mixture was cooled to 0°C and hydrochloric acid (1 milliliter, 10%) was  
55 added to the mixture. The resulting solid was separated by filtration, washed twice with ice cold water (15 milliliters), and dried in vacuo at 50°C overnight to yield 1.4 grams of the product. The reaction scheme was as follows:



#### B. Preparation of Silicated Fluorescent Particles

To 1350 milliliters of deionized water was added 24.4 grams of a polyethylene oxide-polypropylene oxide-polyethylene oxide block copolymer (Pluronic F-68) and 6.2 milliliters of tetraethoxysilane, and the resulting dispersion was stirred vigorously at room temperature for 2 hours. Thereafter, 135 milliliters of 11 molar aqueous ammonium hydroxide was added to the mixture and the mixture was stirred overnight at room temperature. Subsequently, a suspension of 0.99 gram of N-(4,6'-dichloro-3,4,5-triazin-2-yl)-N-ε-(5"-dimethylamino-1"-naphthalene sulfonyl)-lysine in 12.5 milliliters of water prepared as described in paragraph (A) of this Example was added to a 100 milliliter aliquot of the mixture containing the silicated aggregates, and the resulting



mixture was stirred overnight at room temperature. Excess unreacted dye was removed. The purified mixture was concentrated to 30 milliliters by evaporation of the water under vacuum at room temperature. The fluorescent particles were isolated by freeze drying, resulting in a slightly-yellow highly-fluorescent free-flowing powder (1.64 grams, containing about 29 percent by weight of the fluorescent dye, from UV absorption at 329 nanometers, using dansyl lysine as a model compound).

#### C. Preparation of a Fluorescent Ink

An ink composition was prepared by adding 1 milliliter of ethylene glycol to 9 milliliters of water containing 0.5 gram of the slightly-yellow highly-fluorescent particles obtained as described in paragraph (B) of this Example. The resulting solution was filtered through a 0.45  $\mu$ m filter to obtain an ink.

#### D. Printing Tests

The ink prepared as described in paragraph (C) of this Example was tested as above. The prints obtained were invisible to the eye but were strongly fluorescent when examined under ultraviolet lamps emitting at either 254 nanometers or 366 nanometers. Extremely high contrast was observed for images printed on the bond paper (non-fluorescent paper). The contrast was lower for the images on the 4024 paper, which contains a fluorescent brightener, but the images were easily detectable. No feathering of the prints was observed on either the felt or the wire sides of the papers. Prints on both papers exhibited very high wasterfastness, as exemplified by the following test: a printed solid area was cut in two parts, and one half was soaked in water for 2 minutes and subsequently air dried. The fluorescence emissions from both halves were measured with a SPEX fluorescence spectrometer. No decrease in fluorescence intensity was detected in the washed half compared to the untreated half.

#### EXAMPLE XVII

##### Red Ink Containing Fluorescent Particles

A red ink composition was prepared as described in Example XI. To the ink thus prepared was added 80 milliliters of a solution of fluorescent particles prepared as described in part (A) of Example XIV. The resulting mixture was stirred to obtain a homogeneous solution, resulting in an ink containing red particles and substantially colorless fluorescent particles.

#### EXAMPLE XVIII

##### Cyan Ink Containing Fluorescent Silicated Particles

A cyan ink composition was prepared as described in Example 1. To the ink thus prepared were added 80 milliliters of a solution of fluorescent silicated particles prepared as described in part (B) of Example XII. The resulting mixture was stirred to obtain a homogeneous solution, resulting in an ink containing cyan particles and substantially colorless fluorescent silicated particles.

#### EXAMPLE XIX

##### Magenta Silicated Ink Containing Fluorescent Particles

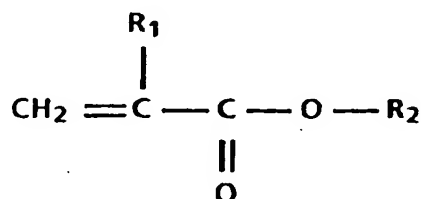
A magenta silicated ink composition was prepared as described in Example IV. To 9.0 milliliters of the ink thus prepared were added 0.50 g of fluorescent particles prepared as described in part (A) of Example XV. The resulting mixture was stirred to obtain a homogeneous solution, resulting in an ink containing magenta silicated particles and substantially colorless fluorescent particles.

#### Claims

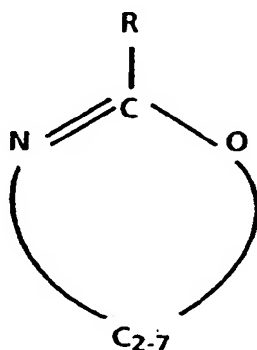
1. An ink composition, which comprises an aqueous liquid vehicle and particles of an average diameter of 100 nanometers or less which comprises micelles of block copolymers of the formula ABA, wherein A represents a hydrophilic segment, and B represents a hydrophobic segment, and wherein dye molecules are

covalently attached to the micelles.

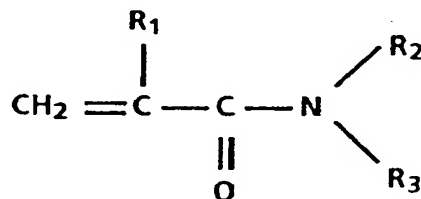
2. An ink composition according to claim 1, wherein the A segments of the block copolymers are of monomers of oxyethylenes, aminoethylenes, vinyl carboxylic acids or their corresponding esters of the general formula:



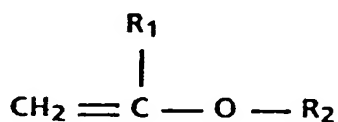
wherein  $\text{R}_1$  and  $\text{R}_2$  are independently selected from hydrogen and alkyl groups with from 1 to 20 carbon atoms, oxazolines of the general formula



wherein  $\text{R}$  is hydrogen, an alkyl group with from 1 to 6 carbon atoms, or benzyl and the ring has from 2 to 7 carbon atoms in addition to the carbon atom situated between the nitrogen and oxygen atoms, acrylamides of the general formula



wherein  $\text{R}_1$  is hydrogen, methyl, or ethyl, and  $\text{R}_2$  and  $\text{R}_3$  are independently selected from hydrogen, alkyl groups with from 1 to 4 carbon atoms, hydroxyalkyl groups with from 1 to 4 carbon atoms, and amino-substituted alkyl groups, vinyl ethers of the general formula



wherein  $\text{R}_1$  is hydrogen, methyl or ethyl, and  $\text{R}_2$  is hydroxy-substituted alkyl groups, amino-substituted alkyl groups, or mixtures thereof.

3. An ink composition according to claim 1 or 2, wherein the B segment of the block copolymers is of monomers of oxypropylenes, vinyl monomers, acrylic monomers and esters of monocarboxylic acids, olefins or mixtures thereof.
- 5 4. An ink composition according to any preceding claim, wherein the block copolymers are ABA block copolymers, wherein the A blocks are polyethylene oxide, and the B block is polypropylene oxide; ABA block copolymers wherein the A blocks are 2-hydroxyethyl vinylether polymers, and the B block is a polymer of butyl vinyl ether or ABA block copolymers wherein the A blocks are polyethylene oxide and the B block is a polymer of 2-hydroxyethyl methacrylate, or mixtures thereof.
- 10 5. An ink composition as claimed in any preceding claim, wherein the micelles have silica precipitated therein.
6. An ink composition as claimed in any preceding claim, wherein the dye molecules are detectable when exposed to radiation outside the visible wavelength range.
- 15 7. An ink composition according to claim 5, wherein the dye molecules are substantially colorless
8. An ink composition according to any preceding claim, wherein at least some of the particles are visibly colored.
- 20 9. An ink composition according to claim 8, wherein the colored dye is a reactive dye.
10. An ink composition as claimed in any preceding claim, containing a visible colorant consisting of pigments, dyes, or mixtures thereof.
- 25 11. An ink marking process in which an ink as claimed in any preceding claim is used as the ink droplet medium.
- 30 12. A printing process which comprises (1) incorporating into an ink jet marking apparatus an ink composition as claimed in any of claims 1 to 10, and (2) causing droplets of the ink to be ejected in an imagewise pattern onto a substrate, thereby generating images on the substrate.



European Patent  
Office

## EUROPEAN SEARCH REPORT

Application Number

DOCUMENTS CONSIDERED TO BE RELEVANT			EP 91305819.4
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. CL.5)
X	DATABASE WPI, NO. 80-88 825 DERWENT PUBLICATIONS LTD., London, GB * Abstract * & JP-A-55 137 166 (ELED) 26-10-1980 --	1	C 09 D 11/10 B 41 M 1/42
X	EP - B1 - 0 092 578 (THE GILLETTE COMPANY) * Claims * --	1	
A	US - A - 3 784 502 (R. GOBRAN) * Claims; abstract * --	1	
A	DATABASE WPIL, NO. 82-00 866 DERWENT PUBLICATIONS LTD., London, GB * Abstract * & JP-A-56 155 262 01-12-1981 -----	1, 12	TECHNICAL FIELDS SEARCHED (Int. CL.5)  C 09 D 11/00 B 41 M 1/00 C 08 F 293/00 C 08 F 295/00 C 08 F 297/00 C 08 F 299/00
The present search report has been drawn up for all claims			
Place of search VIENNA		Date of completion of the search 30-09-1991	Examiner PAMMINGER
CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document			